# HYDROLOGIC EVALUATION OF THE HAYSTACK BUTTE AREA WITH EMPHASIS ON POSSIBLE DISCHARGE OF CLASS-I WASTES, EDWARDS AIR FORCE BASE, CALIFORNIA



U.S. GEOLOGICAL SURVEY. Water Resources Division.

Water-Resources Investigations 7-75

Prepared in cooperation with
U.S. Air Force Rocket Propulsion Laboratory

# HYDROLOGIC EVALUATION OF THE HAYSTACK BUTTE AREA WITH EMPHASIS ON POSSIBLE DISCHARGE OF CLASS-I WASTES, EDWARDS AIR FORCE BASE, CALIFORNIA

By Jerry L. Hughes

U.S. GEOLOGICAL SURVEY, Water Resources Division.

Water-Resources Investigations 7-75

Prepared in cooperation with

U.S. Air Force Rocket Propulsion Laboratory

7210-18

April 1975

UNITED STATES DEPARTMENT OF THE INTERIOR

Rogers C. B. Morton, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

---

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
345 Middlefield Road
Menlo Park, Calif. 94025

CONTENTS



ILLUSTRATIONS

## TABLES



## CONVERSION FACTORS

Factors for converting English units to the International System of Units (SI) are given below to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

| *English* | *Multiply by* | *Metric* |
|---|---|---|
| acres | $4.047 \times 10^{-1}$ | ha (hectares) |
| acre-ft (acre-feet) | $1.233 \times 10^{-3}$ | $hm^3$ (cubic hectometres) |
| acre-ft/yr (acre-feet per year) | $1.233 \times 10^{-3}$ | $hm^3$/yr (cubic hectometres per year) |
| ft (feet) | $3.048 \times 10^{-1}$ | m (metres) |
| $ft^2$ (square feet) | $9.290 \times 10^{-2}$ | $m^2$ (square metres) |
| ft/d (feet per day) | $3.048 \times 10^{-1}$ | m/d (metres per day) |
| ft/mi (feet per mile) | $1.890 \times 10^{-1}$ | m/km (metres per kilometre) |
| ft/yr (feet per year) | $3.048 \times 10^{-1}$ | m/yr (metres per year) |
| gal/d (gallons per day) | $3.785 \times 10^{-3}$ | $m^3$/d (cubic metres per day) |
| gal/min (gallons per minute) | $6.309 \times 10^{-2}$ | l/s (litres per second) |
| in (inches) | 2.540 | cm (centimetres) |
| in (inches) | 2.540 x 10 | mm (millimetres) |
| in/yr (inches per year) | 2.540 | cm/yr (centimetres per year) |
| in/yr (inches per year) | $2.540 \times 10^{-2}$ | m/yr (metres per year) |
| in/yr (inches per year) | 2.540 x 10 | mm/yr (millimetres per year) |
| mi (miles) | 1.609 | km (kilometres) |
| $mi^2$ (square miles) | 2.590 | $km^2$ (square kilometres) |
| $yd^3$ (cubic yards) | $7.646 \times 10^{-1}$ | $m^3$ (cubic metres) |

# HYDROLOGIC EVALUATION OF THE HAYSTACK BUTTE AREA WITH EMPHASIS ON POSSIBLE DISCHARGE OF CLASS-I WASTES EDWARDS AIR FORCE BASE, CALIFORNIA

---

By Jerry L. Hughes

---

## ABSTRACT

The discharge of 3 acre-feet ($4 \times 10^{-3}$ cubic hectometres) per year of Class-I wastes in the Haystack Butte area of Edwards Air Force Base, Calif., has been proposed by the Air Force. Evaporation in this arid basin exceeds the 4 inches (100 millimetres) of annual precipitation. Fifteen test holes, ranging in depth from 40 to 240 feet (12 to 73 metres) below land surface, indicate that ground water occurs mostly in Tertiary volcanic and sedimentary rocks overlying pre-Tertiary quartz monzonite. Depth to water averages about 100 feet (30 metres) below land surface. Hydraulic conductivity of cores of Tertiary rock taken from a test hole at depths of 9 to 88 feet (2.7 to 27 metres) below land surface suggests values of $6.9 \times 10^{-5}$ to $4.9 \times 10^{-3}$ feet per day ($2.1 \times 10^{-5}$ to $1.5 \times 10^{-3}$ metres per day). Petrographic analyses of these cores indicate a material consisting mostly of weathered volcanic rocks with a moderate concentration of montmorillonite clay.

The water-level gradient averages about 4 feet per mile (0.76 metre per kilometre). Ground-water discharge through a narrow gap in the southeastern part of the basin is calculated to be $3.8 \times 10^{-4}$ acre-feet ($4.7 \times 10^{-7}$ cubic hectometres) per year. After leaving the basin, the underflow becomes part of a regional flow system discharging into Harper Lake playa.

An increase in the underflow from $3.8 \times 10^{-4}$ acre-feet ($4.7 \times 10^{-7}$ cubic hectometres) per year to 3 acre-feet ($4 \times 10^{-3}$ cubic hectometres) per year may result in an undesirable surface-water flow by increasing the saturated thickness of the aquifer near the narrow gap in the southeastern part of the basin. Also, the very low hydraulic-conductivity values suggest that some difficulties may exist in percolating 3 acre-feet ($4 \times 10^{-3}$ cubic hectometres) per year of wastes resulting in possible saturation of the ground surface outside the boundaries of the potential Class-I site. Because the rate of evaporation is very high (116 inches or 294.6 millimetres per year) in the study area, many of the problems associated with the percolation of the waste water and the subsequent changes in ground-water movement could be minimized by evaporating the wastes to complete dryness.

The quality of the ground water in the basin is generally unsuitable for domestic, industrial, and irrigation purposes. The concentration and type of chemical constituents in the ground water suggest slow circulation in a geologic environment with soluble minerals.

## INTRODUCTION

Disposal of toxic, industrial wastes is costly and its environmental impact often difficult to assess. Occasionally fluids from these wastes are allowed to percolate into the ground without consideration of the geologic and hydrologic setting, and consequently of the potential hazard to the environment. Out of sight, out of mind is not a prudent philosophy when toxic wastes are discharged to earth materials, especially where downward percolation to the water table followed by ground-water movement could, at some time, affect usable water supplies.

Edwards Air Force Base (EAFB), Calif., the second largest Air Force base in the United States, is northeast of Lancaster in the Mojave Desert (fig. 1). The primary function of EAFB is experimental flight and rocket testing. The Haystack Butte area is in the eastern part of EAFB and is used primarily for the testing of rocket propellants. Waste products of the testing are solid and liquid rocket propellants and contaminated soils and metals. In the past these wastes have been containerized, placed in abandoned mine shafts, burned, exploded, or removed from EAFB by civilian contract for disposal in other areas.

The purpose of this study was (1) to appraise the climatic, geologic, and hydrologic conditions in an area of EAFB near Haystack Butte for possible discharge of Class-I wastes, and (2) to evaluate, if possible, the effects of previous disposal of solid and liquid wastes into two abandoned mine shafts.

The scope of the study included:

1. Collecting data on the geology, hydrology, climate, and chemical quality of the ground water.
2. Augering or drilling sufficient test holes to provide information on geology, water levels, and hydraulic characteristics of geologic units.
3. Evaluating the possible results of discharging Class-I wastes in the Haystack Butte area.

This report was prepared in cooperation with the U.S. Air Force Rocket Propulsion Laboratory as part of an investigation of the discharge of Class-I wastes at Edwards Air Force Base, Calif.

### Acknowledgments

Many persons at the U.S. Air Force Rocket Propulsion Laboratory, EAFB, provided information and assistance for this study. Special appreciation is given to Major James D. Wallace, USAF, and his staff in the Bioenvironmental Section.

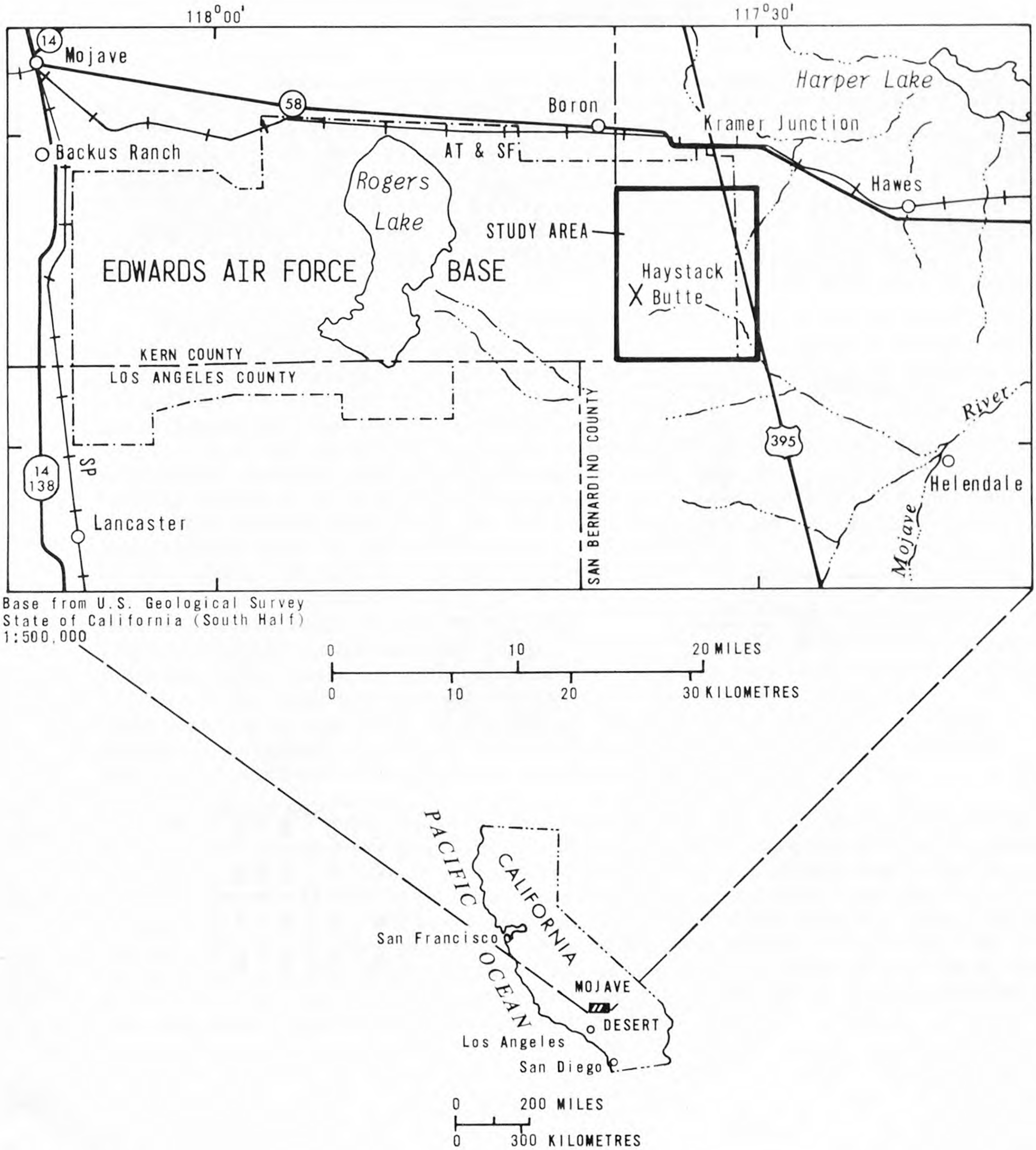
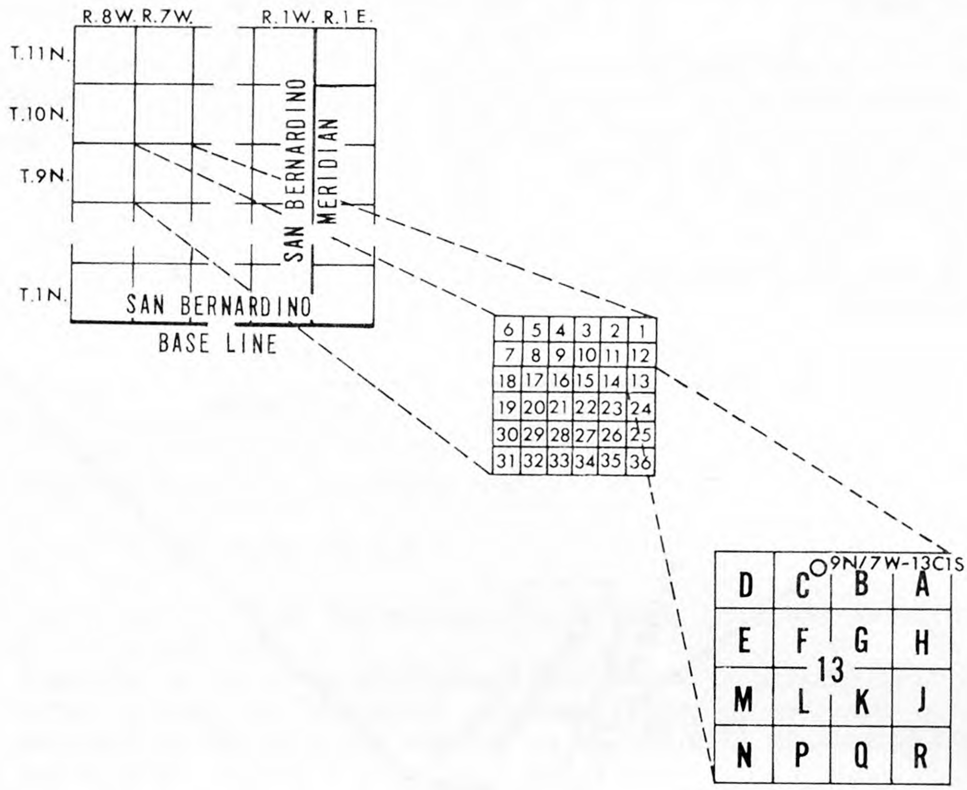



FIGURE 1.--Index map showing location of study area.

## Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well number 9N/7W-13C1S the first two segments designate the township (T. 9 N.) and the range (R. 7 W.); the third number gives the section (sec. 13); and the letter indicates the 40-acre (16-ha) subdivision of the section, as shown in the accompanying diagram. The final digit is a serial number for wells in each 40-acre (16-ha) subdivision. The final letter (S) indicates the San Bernardino base line and meridian.



## REQUIREMENTS FOR DISPOSAL OF CLASS-I WASTES

"Class-I waste disposal sites are those at which complete protection is provided for all time for the quality of ground and surface waters from waste deposited therein and against hazard to public health and wildlife resources" (California Water Resources Control Board, 1972, p. 19). With the possible exception of some radioactive material, there are no limits as to the types or concentrations of wastes that can be discharged to an unlimited Class-I site. Great care needs to be taken to insure that the parameters outlined by the requirements for a Class-I site are fully investigated.

Requirements for an unlimited Class-I site, as set forth by the State of California (1972), briefly include: (1) Site cannot be subject to inundation or washout, (2) geologic conditions must be naturally capable of preventing or modified to prevent vertical hydraulic continuity between liquids and gases emanating from the waste in the site and usable surface or ground water, (3) sites shall not be located over zones of active faulting or in an area where changing geologic conditions would impair the competence of the natural features or artificial barriers to prevent continuity between wastes and usable ground water, and (4) fractures and fissures of questionable permeability must be sealed to prevent migration of liquids or gases to usable water. Should usable ground water exist beneath the proposed site, the site must be modified to prevent percolation. Also, should the site meet all above requirements except (1) above, the site may be accepted as a limited Class-I waste-disposal site. "Wastes disposed of in limited Class-I disposal sites shall be subject to waste discharge requirements which include limits on the type and quantity of material entering the site, the concentration of material in the waste disposed of on the site, and the amount of material present or remaining on the site after evaporation of liquids" (California Water Resources Control Board, 1972, p. 29).

The types of data collected and interpreted for this study were oriented to the requirements set forth by the State of California for a Class-I waste-discharge site. The use of, or the reference to, the requirements for a Class-I waste-disposal site should not be taken to suggest that the U.S. Geological Survey either supports or confirms the requirements. Also, it is not the purpose of this report to propose an area suitable for receiving Class-I wastes. The final decision as to the acceptability of the data, the interpretation, and the area appraised for the discharge of Class-I wastes is the responsibility of the State of California.

## NATURE OF WASTES TO BE DISCHARGED

At present (1974) wastes from rocket testing are partly treated and stored, or removed from the base by civilian contract for disposal elsewhere. During 1974 a more advanced waste-treatment facility is planned for construction on EAFB. The proposed facility will include a primary treatment section with discharge to lined evaporation ponds. The toxic residue in the evaporation ponds will be transferred to a Class-I site at EAFB, should such a site be approved by the State of California.

Initially there will be a need for both a one-time and a continuous disposal of a myriad of chemical compounds and wastes to a Class-I site (written commun., Major James D. Wallace, USAF, 1972). Based on present-day (1974) operations and propellant usage, the types of chemical compounds to be discharged on either a one-time or a continuous program might include: 4,000 $yd^3$ ($3.1 \times 10^3$ $m^3$) of soil contaminated with high-fired beryllium oxide; stainless-steel tanks containing plating wastes of cyanide and chromium compounds; filters from hydraulic and aviation lines; an assortment of industrial chemicals; and toxic residues from the evaporation ponds mentioned above.

The residue from the treatment facility will be the chemical products of primary treatment in the plant, which includes both combustion and scrubbing with sodium hydroxide. Oxidation and evaporation in the evaporation ponds will further concentrate the wastes from the plant. It has been proposed by the U.S. Air Force that the residue or sludge in the evaporation ponds be moved to a Class-I site three or four times a year.

The chemical composition of the sludge to be removed from the evaporation ponds will depend on the types of propellants used and the solubility of their combustion products in the sodium hydroxide scrubbing solution. The predominant types of chemical substances to be burned include solid propellants, hydrazine and its derivatives, hydrazine-fuel mixtures, nitric acid, and nitrogen oxides [nitrogen tetroxide ($N_2O_4$), and fuming nitric acids, which include a mixture of nitrite ($NO_2$), nitrates ($NO_3$), and hydrogen fluoride (HF)].

## HYDROLOGY

### Precipitation and Evaporation

The climate of the Haystack Butte area is arid with an average annual precipitation of 4.05 in (102.8 mm). Weather data provided by EAFB (written commun., 1973) indicate that nearly all the precipitation occurs as rain during the winter months of October through February. Thundershowers occur infrequently during summer months (June through September), and although local in extent, a single storm may be of sufficient intensity to constitute a high percentage of the total annual precipitation over its area of occurrence. On the basis of nearly 30 years of record (1942 through 1971) at EAFB, a thundershower of 0.26-0.5 in (6.6-12.7 mm) has a probability of recurring once in a hundred years. The maximum rainfall recorded at EAFB during summer months was 1.1 in (27.9 mm) in August 1965. Data on the time duration of this storm are not available, but the storm was probably limited to a few hours. Winter storms are generally less intense but of longer duration than summer thundershowers. The maximum recorded winter rainfall for a 24-hour period was 2.49 in (63.2 mm) in February 1944. The recurrence frequency of a storm of this magnitude based on the 30 years of record is less than once in a hundred years.

The average annual temperature at EAFB is 62°F (17°C). Temperatures in excess of 100°F (38°C) have been recorded during the months of May through September. The highest temperature recorded was 113°F (45°C) in July 1961. Although nighttime winter temperatures are often below freezing, daytime temperatures are frequently above 60°F (16°C).

The dominant wind direction is of primary importance in the selection of a Class-I site because winds can carry contaminated solids and gaseous wastes away from the disposal area and possibly to populated areas. Surface-wind data provided by EAFB indicate that the prevailing wind direction is from west to east. Winds blow from south to north less than 5 percent of the time. The populated areas that are close to the Haystack Butte area and that could be affected by surface winds from the south are Kramer Junction and Boron (fig. 1).

Evaporation at EAFB can be approximated from evaporation records collected at nearby Backus Ranch and Mojave (fig. 1) climatological stations (table 1; data from National Weather Service, 1936-72) where the average annual evaporation is 116.56 in (2,960 mm). A comparison of average surface winds, temperature, and precipitation data at EAFB with the data from these climatological stations suggests that a transfer of the evaporation data to the Haystack Butte area can be made with reasonable confidence.

TABLE 1.--*Average monthly and annual evaporation at Backus Ranch (1936-62) and Mojave (1964-72)*

| | Average evaporation in inches, using U.S. Weather Bureau Class A evaporation pan | | | | |
|---|---|---|---|---|---|
| Month | Backus Ranch[1] | Mojave[2] | Month | Backus Ranch[1] | Mojave[2] |
| January | 3.05 | -- | July | 18.44 | 18.11 |
| February | 3.71 | -- | August | 17.57 | 16.65 |
| March | 6.37 | 9.84 | September | 12.62 | 12.25 |
| April | 9.63 | 10.63 | October | 7.73 | 8.41 |
| May | 13.30 | 13.95 | November | 4.40 | 4.61 |
| June | 16.73 | 15.47 | December | 3.01 | -- |

[1]The 27-year average at Backus Ranch is 116.56 inches.
[2]Records incomplete.

## Surface Water

The area investigated for Class-I waste-disposal sites is a topographically open basin of gentle relief (see fig. 2). The surface-water drainage basin measures 37 $mi^2$ (96 $km^2$). Many of the channels carrying surface-water runoff are not well defined and are difficult to locate, suggesting that periods of runoff are infrequent or of small magnitude. Surface-water discharge from the basin occurs through two small gaps in secs. 21 and 29, T. 9 N., R. 6 W. (see fig. 2). The town of Helendale (fig. 1) is about 12 mi (19 km) downgradient from these outlets.

The requirements of the State of California for the location of an unlimited Class-I site stipulate that inundation by surface-water runoff cannot occur. However, should calculations indicate a waste-disposal site will not be inundated by surface-water runoff equal to or less than a 100-year flood, it may be considered as a limited Class-I site. This aspect of the investigation is important because waste water from a washed-out Class-I site reaching the town of Helendale might affect not only the quality of water in that area but conceivably the water supply of the large ground-water basin to the east along the Mojave River (fig. 1).

A direct calculation of the surface-water discharge in a 100-year flood requires a series of flow measurements over a range in stage. Because no direct measurements of surface flow have been made in the Haystack Butte area, the possibility of a Class-I site being inundated by a 100-year flood must be estimated by determining the altitude to which a 100-year flood would fill the basin, assuming the Class-I site is at or above that altitude and the basin has no surface outlet.

The National Weather Service (1972) estimated that a 3-in (76-mm) rainfall during a 24-hour period represents a 100-year storm for this basin. The largest recorded rainfall at EAFB during nearly 30 years of record was 2.49 in (63.2 mm) for a 24-hour period in February 1944.

The volume of water in a 3-in (76-mm) rainfall on a basin of 37 $mi^2$ (96 $km^2$) is approximately 6,000 acre-ft (7.4 $hm^3$). The actual rainfall available as runoff is, however, a function of the infiltration rate. The infiltration rate can be varied to represent conditions during a summer thunderstorm by assuming a minimum infiltration and therefore maximum runoff, or during a winter storm of 24-hour duration by increasing the percentage of rainfall lost to infiltration. Because there is no reasonable way to predict the distribution of rainfall, its intensity, or several other factors that influence infiltration rates (for example, soil moisture and vegetal cover), absolute maximum runoff conditions can be estimated by assuming zero infiltration. If a single, 100-year storm is assumed to fall within an infinitely small period of time on an area totally covered by an impermeable substance, the total runoff would be 6,000 acre-ft (7.4 $hm^3$) and would fill the basin to about the 2,800-ft (853-m) altitude, assuming the outlets in secs. 21 and 29, T. 9 N., R. 6 W., do not exist.

Realistically, there will always be some infiltration of rainfall. Also, because there is an outlet for part of the runoff, the water could not rise to the 2,800-ft (853-m) land-surface contour. The magnitude of the flood described is therefore assumed to be considerably greater than would result from a storm of 100-year frequency. A Class-I waste-discharge site located above the 2,800-ft (853-m) contour and away from surface-water channels should be reasonably safe from inundation.

## Ground Water

### Geology

The geology of the Haystack Butte area was described by Dibblee (1960) who indicated that the rock units in the area can be grouped into three main divisions, each separated by major unconformities. The divisions are: crystalline rocks of pre-Tertiary age; volcanic, pyroclastic, and sedimentary rocks of Tertiary age; and alluvial deposits of Quaternary age (fig. 2). The most common pre-Tertiary rock in the study area is quartz monzonite. The quartz monzonite underlies the entire study area and makes up the bedrock or basement complex. It is massive, dense, light gray, and almost totally impermeable to ground water except along fracture systems.

The Tropico Group makes up most of the Tertiary rocks exposed in the study area. This group was described by Dibblee (1960) as a sequence of lacustrine, fluviatile, and volcanic strata composed mostly of sandstone, clay shale, limestone, dolomite, shale, tuff, and basalt (fig. 2). The hydraulic conductivity (permeability) of the Tropico Group is in part a function of the individual rock type and can be very low in shale or moderately high in sandstone, basalt, and carbonaceous rock.

Quaternary deposits consist of fanglomerate and older alluvium of Pleistocene age, and windblown sand, playa clay, and alluvial sand and gravel deposits of Holocene age. The fanglomerate crops out extensively in the hills on the north edge of the study area and the older alluvium in the southeastern part. Windblown sand and alluvial sand and gravel cover most of the study area (fig. 2). Playa clay occurs only in the central part of the area. The Quaternary deposits are locally in direct contact with the quartz monzonite bedrock where the Tropico Group was not deposited or has been removed by erosion. The hydraulic conductivity of windblown sand and alluvial sand and gravel is generally very high in contrast to that of the playa clay, which is usually very low.

Three principal faults in the study area were described by Dibblee (1960). They are the Spring fault, the Kramer Hills fault, and the Leuhman fault (fig. 2). Spring and Kramer Hills faults are generally parallel and are described as scissor-type faults that have produced horst and graben features. Leuhman fault also parallels the above faults, but its trace is totally concealed by alluvial deposits.

## EXPLANATION

QUATERNARY

*Holocene*

Qa — Alluvial sand and gravel

Qc — Playa clay

Qs — Windblown sand

*Pleistocene*

Qoa — Older alluvium

Qf — Fanglomerate

TERTIARY

Tt — Tropico Group

Includes sandstone, clay shale, limestone and (or) dolomite, caliche, shale, rhyolite, andesite, dacite, tuff, and olivine basalt

PRE-TERTIARY

pTr — Pre-Tertiary rocks

Consisting mostly of quartz monzonite. Also includes granite and dike (intrusive) rocks

Contact

U / D — Fault

Dashed where approximately located; dotted where concealed; queried where doubtful; U, upthrown side; D, downthrown side

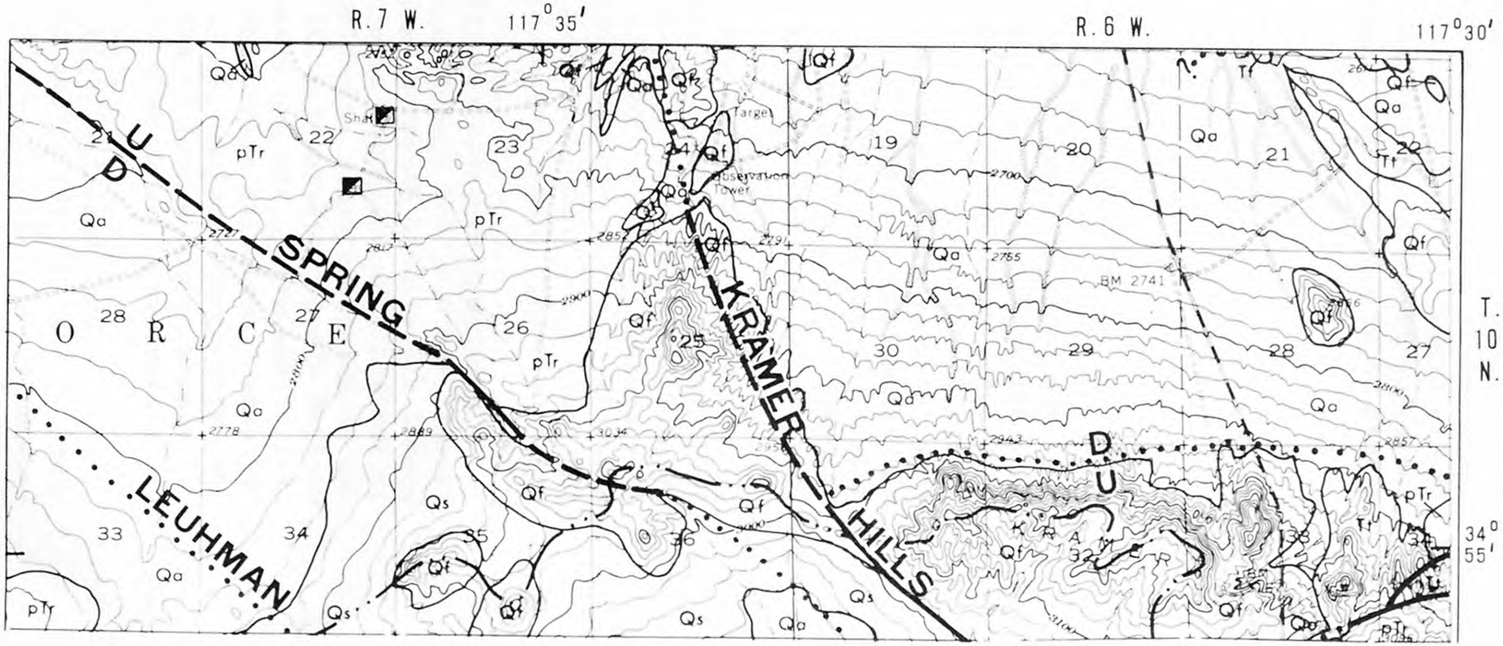
Basin boundary

Dashed where open

10J1 — Unused well and number

18D1 — Test hole and number

Mine shaft



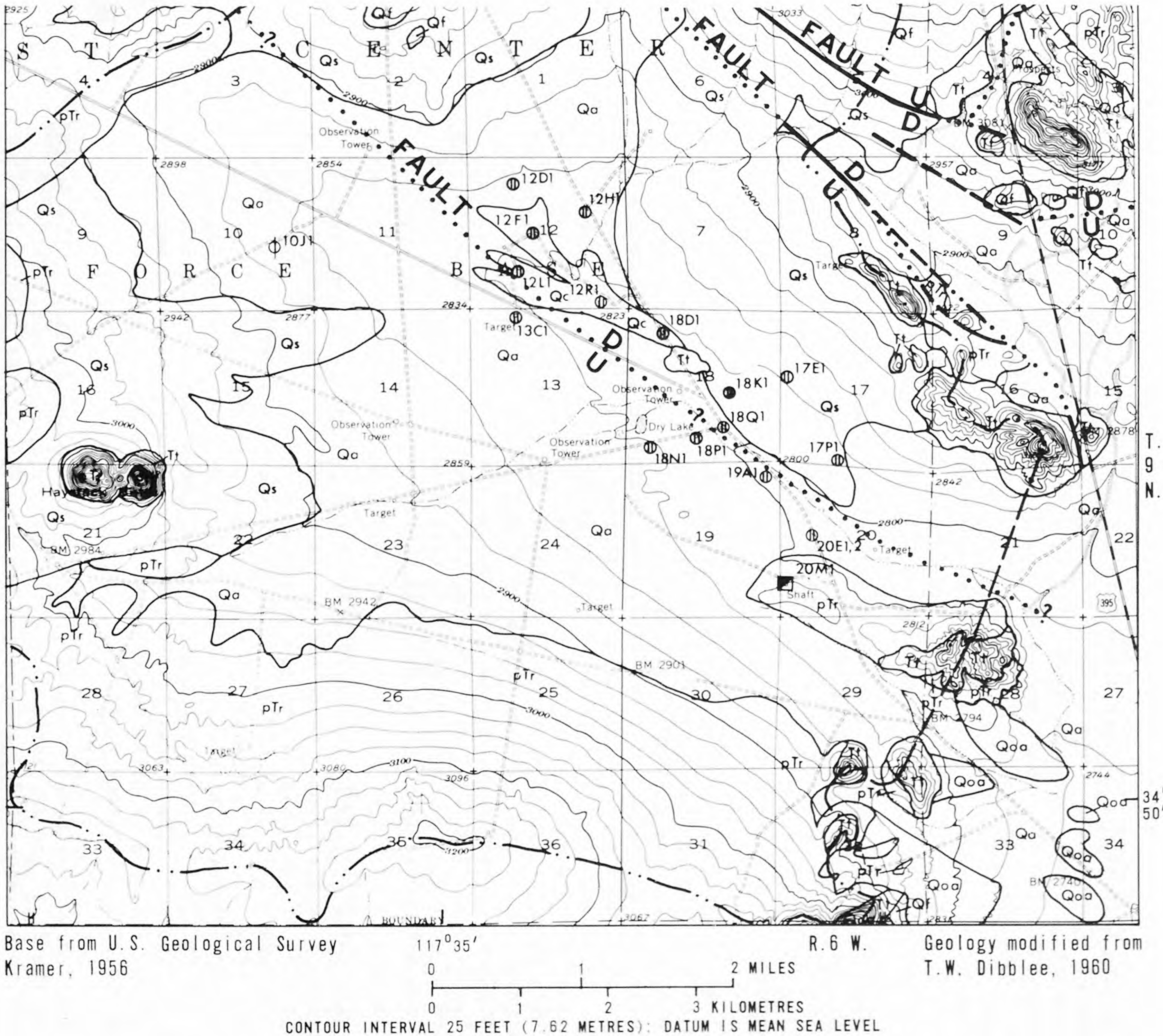



FIGURE 2.--Geology, location of test holes, and ground-water quality sampling points.

## Test Drilling

During this study, 15 test holes were drilled or augered (fig. 2) for lithologic information. Logs of these holes are in the appendix attached to this report. These holes were cased with 2-in (5.08-cm) outside diameter polyvinyl chloride (PVC) pipe and ranged in depth from about 40 to 240 ft (12 to 73 m; app.) below land surface. One hole was completed with two casings, one is 185.5 ft (56.6 m) deep and the other is 133 ft (40.5 m) deep. Information on subsurface geology was also provided from a previously drilled well 9N/7W-10J1 (254 ft or 77 m deep), an abandoned mine shaft 9N/6W-20M1 (approximately 125 ft or 38 m deep), and cores from test hole 9N/6W-19A1.

Test drilling indicated that the playa deposits near sec. 12, T. 9 N., R. 7 W., are generally less than 15 ft (4.5 m) thick and, for the most part, rest unconformably on older alluvial deposits or the Tropico Group. Test drilling also indicated that the areal distribution of the playa deposits are as described by Dibblee (1960).

Logs of test holes 9N/6W-18N1, 18P1, 20E1, and 9N/7W-13C1 drilled on the south side of the Leuhman fault show mostly weathered and unweathered quartz monzonite overlain by Quaternary alluvium. The alluvial deposits were generally less than 15 ft (4.5 m) thick. The weathered quartz monzonite appears as a light-gray to rust-colored (oxidized) clay with some sand-size quartz grains and large quantities of muscovite and biotite mica. The weathered bedrock, where penetrated by drilling of test holes 9N/6W-18N1 and 20E1, ranged in thickness from 92 to 102 ft (28 to 31 m) encountering the unweathered quartz monzonite at depths of 96 and 137 ft (29 and 42 m) below land surface. Unweathered bedrock crops out at the mine shaft in sec. 20, T. 9 N., R. 6 W. (fig. 2). With the possible exception of a thin, 20-ft (6-m) section of weathered volcanic rocks(?) in test hole 9N/6W-20E1, the Tropico Group was not penetrated by test drilling on the south side of the Leuhman fault.

Test holes drilled on the north side of the Leuhman fault consistently penetrated both the Tropico Group and quartz monzonite. The quartz monzonite on this side of the fault was mostly unweathered and occurred at depths of 139, 100, and 112 ft (42.4, 30.5, and 34 m) in test holes 9N/6W-17E1, 17P1, and 19A1 (fig. 2). A comparison of the occurrence of the weathered and unweathered bedrock on both sides of the fault indicates a discontinuity of about 100 ft (30.5 m), with the lower, or downthrown side to the south as shown in figure 2. The change in altitude of the quartz monzonite may result from either faulting or differential erosion of the bedrock prior to deposition of the Tertiary rocks.

The Tropico Group was penetrated in most test holes drilled on the north side of the fault and consisted mostly of clay-shale, sandstone, weathered volcanic rocks (andesite?), and olivine basalt. Where penetrated by drilling, the olivine basalt was almost always in direct contact with quartz monzonite (see log of test hole 9N/6W-19A1, appendix).

A correlation of geologic units described from the test drilling indicates that the Tropico Group is wedge shaped and disappears near the Leuhman fault. This distribution of the Tropico Group may have resulted from either erosion after displacement by the Leuhman fault, or deposition of the Tropico Group on an irregular bedrock surface. However, the occurrence of the Tropico Group in test holes 9N/6W-19A1 and 20E1, which were drilled directly on and to the south of the fault, suggests that the Tertiary rocks may have been deposited subsequent to faulting. This would indicate that the fault, providing it exists, is at least of pre-Tertiary age and that significant movement along it probably has not occurred since that time.

In general, results obtained by test drilling suggest that most of the ground-water flow in the study area is probably restricted to the more permeable Tropico Group and that little, if any, ground water is transmitted by the clay-filled fractures in the bedrock. Ground-water flow may occur in the weathered bedrock zone but is probably insignificant because of the zone's very high clay content and low hydraulic conductivity.

To estimate the transmissivity and other characteristics of the Tropico Group, test hole 9N/6W-19A1 (fig. 2) was cored from 9 to 55 ft (3 to 17 m) and 80 to 88 ft (24 to 27 m) below land surface. The water level in this test hole is at a depth of 88 ft (27 m). A petrographic analysis of core sections from the 44- and 87-ft (13- and 27-m) depths suggested a highly altered (99 percent weathered) mafic, volcanic rock, low in quartz and moderately high in feldspars (40 percent) and pyroxenes. In the field, this rock resembled weathered andesite.

X-ray analyses of the rock indicated that the feldspars were altered to a montmorillonite clay. By definition (Gary and others, 1972, p. 462) a montmorillonite clay is subject to cation exchange and to swelling when wetted by the introduction of interlayer water. Waste water percolating from a Class-I site and coming in contact with montmorillonite clay in the unsaturated zone would result in expansion of the clay and a reduction in hydraulic conductivity. A reduction in hydraulic conductivity by expansion of the clay can also result from an exchange of the large sodium ion with other smaller cations, provided the clay is not already saturated with sodium. Ample sodium ions should be available in the proposed percolating waste water because of the sodium hydroxide scrub used to treat the wastes.

## Ground-Water Movement

Test drilling in the study area encountered ground water in seven test holes (fig. 3). Water-level data were also available for well 9N/7W-10J1 and the abandoned mine shaft in sec. 20, T. 9 N., R. 6 W. The depth to ground water below land surface ranged from 80 ft (24.4 m) in test holes 9N/6W-20E1 and 20E2 to 141 ft (43 m) in well 9N/7W-10J1.

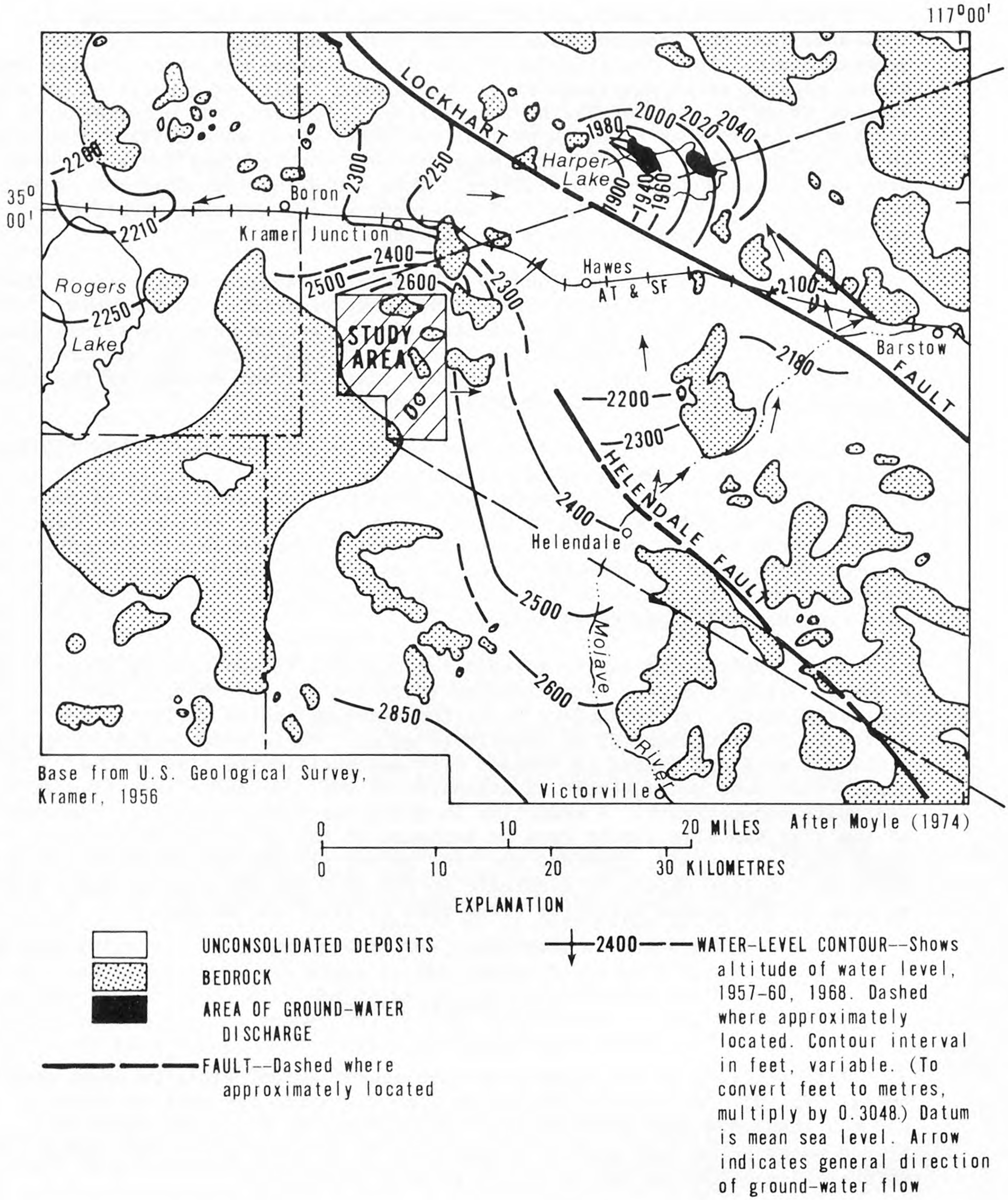



FIGURE 3.--Direction of ground-water flow in region and in study area.

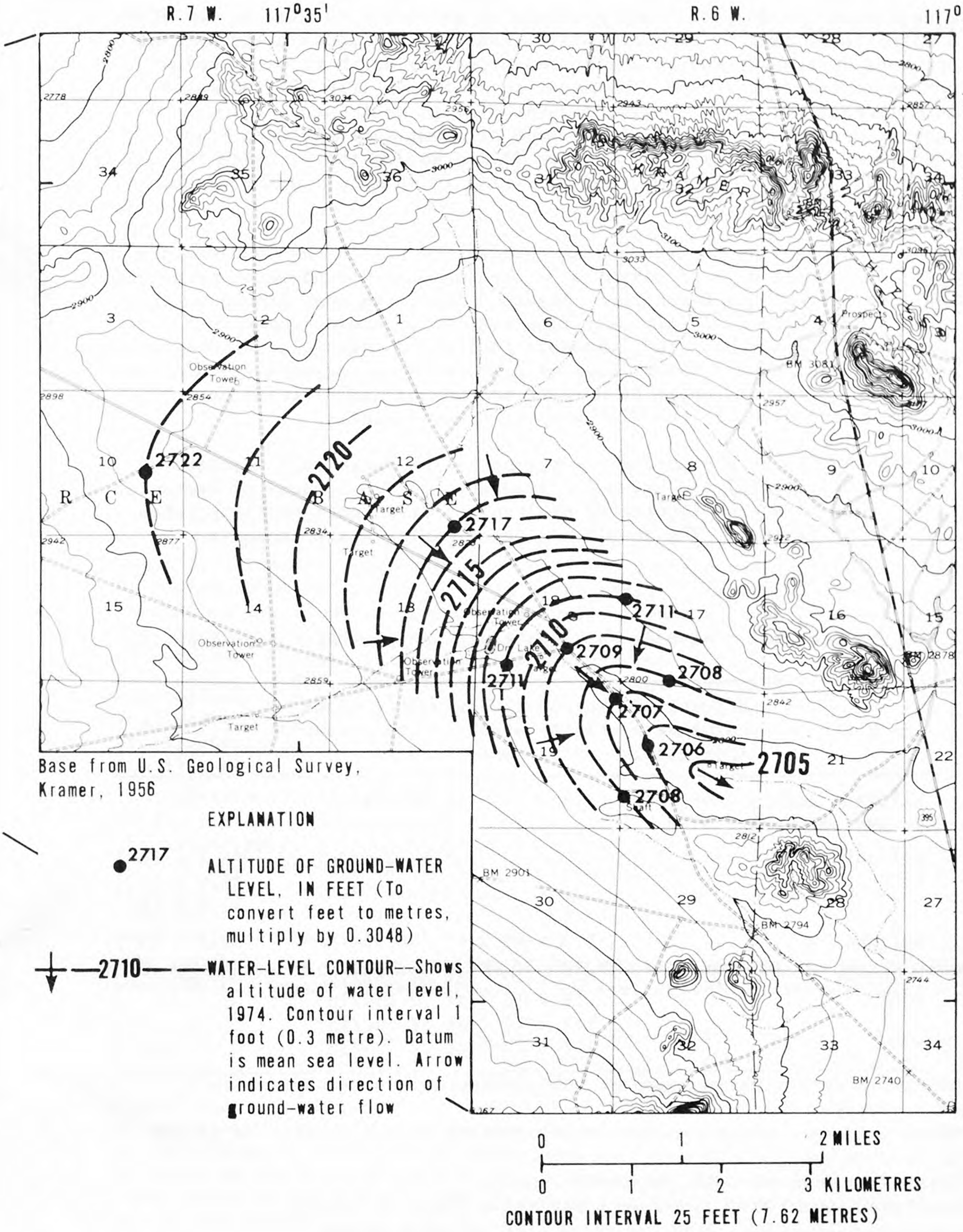



FIGURE 3.--Continued.

To determine the direction and gradient of ground-water flow in the study area, a water-level contour map was constructed from altitudes calculated at each test hole by transit survey and by measuring the depth to water below land surface in each test hole. The detailed inset map (fig. 3) indicates that the principal direction of ground-water flow is southeastward toward a narrow gap in bedrock at an average gradient of about 4 ft/mi (0.76 m/km). The ground-water gradient is about 6 ft/mi (1.1 m/km) in the vicinity of secs. 18 and 20, T. 9 N., R. 6 W., and 2.5 ft/mi (0.48 m/km) in the upper, broader part of the basin.

Ground water leaving the study area through the gap in the southeastern part of the basin will move in response to the regional ground-water gradients toward an area of regional discharge. Figure 3 indicates that ground water leaving the study basin will initially flow eastward, then northeastward toward Hawes passing north of the Helendale fault, and eventually discharge into the Harper Lake area. Harper Lake is a playa and a regional ground-water discharge area. A recent report by Burnett and Taylor (1973) lists Harper Lake as a potential site for the discharge of Class-I wastes.

The velocity ($V$) of ground-water movement in the basin is a function of hydraulic conductivity ($K$) and hydraulic gradient ($I$). Estimates of hydraulic conductivity were made from laboratory analyses of drill-core sections taken from test hole 9N/6W-19A1. The results of these analyses are given in table 2.

TABLE 2.--*Hydraulic determinations for core sections from test hole 9N/6W-19A1*[1]

| Depth of core (ft) | Rock type | Effective porosity (percent) | Vertical hydraulic conductivity at effective stress[2] ($K_v$, ft/d) | Horizontal hydraulic conductivity ($K_H$, ft/d) |
|---|---|---|---|---|
| 9.0 | Alluvium and colluvium(?) | -- | $2.1 \times 10^{-4}$ at 25 lbs/in$^2$ | -- |
| 26 | Volcanic rock | 16.5 | $1.2 \times 10^{-3}$ at 27 lbs/in$^2$ | [3]$3.3 \times 10^{-4}$<br>[4]$6.9 \times 10^{-3}$<br>[5]$7.2 \times 10^{-3}$ |
| 44 | Caliche | 14.4 | $4.9 \times 10^{-3}$ at 165 lbs/in$^2$ | [6]$2.6 \times 10^{-4}$ |
| 87 | Volcanic rock | 11.2 | $6.9 \times 10^{-5}$ at 89 lbs/in$^2$<br>$1.9 \times 10^{-4}$ at 70 lbs/in$^2$<br>$1.2 \times 10^{-4}$ at 52 lbs/in$^2$<br>$5.2 \times 10^{-4}$ at 22 lbs/in$^2$ | -- |

[1]Hydraulic determination made at U.S. Geological Survey Hydraulic Laboratory, Denver, Colo.

[2]Water used in hydraulic-conductivity determinations similar to ground water in study area.

[3]Water from Denver, Colo., domestic supply.

[4]Distilled water with 1,000 mg/l potassium chloride added.

[5]Distilled water with 1,000 mg/l calcium chloride added.

[6]Distilled water with 1,000 mg/l sodium chloride added.

The average velocity ($V$) of ground-water flow in the study area may be estimated from the equation:

$$V = KI \qquad (1)$$

Using a hydraulic conductivity ($K$) of $3 \times 10^{-4}$ ft/d ($1 \times 10^{-4}$ m/d) and an average gradient ($I$) of 5 ft/mi (0.95 m/km), the resultant velocity is $2.8 \times 10^{-7}$ ft/d ($8.5 \times 10^{-8}$ m/d). This is an extremely slow rate of ground-water flow. Increasing the value of hydraulic conductivity to 3 ft/d (0.9 m/d) still resulted in a very slow flow rate of $2.8 \times 10^{-3}$ ft/d ($8.5 \times 10^{-4}$ m/d). Assuming the velocity may be as great as $2.8 \times 10^{-3}$ ft/d or 1 ft/yr (0.3 m/yr), it would require several thousand years for a unit of ground water affected by waste discharge to travel 1 mi (1.6 km) within the basin at present ground-water gradients. Furthermore, this estimate does not take into account the time required for wastes discharged at the surface to percolate 100 ft (31 m) to the zone of saturation, where they would be influenced by the rate and direction of ground-water flow.

The volume of toxic waste water available for infiltration into the basin can be estimated from the volume of wastes to be treated. According to Major James D. Wallace (written commun., USAF, 1973), a maximum of 6,000 gal/d (23 $m^3$/d) or 6.7 acre-ft/yr ($8.3 \times 10^{-3}$ $hm^3$/yr) of wastes are to be discharged to lined evaporation ponds that measure 150 x 75 x 1.5 ft (46 x 23 x 0.46 m). Assuming the long-term average evaporation data collected at Backus Ranch of 116.56 in/yr (3 m/yr; table 1) is applicable, the water content of the sludge to be moved annually from the lined evaporation ponds to the Class-I site will be about 5 acre-ft/yr ($6 \times 10^{-3}$ $hm^3$/yr). This computation is based on the rate of evaporation at Backus Ranch being reduced by a factor of 0.7, which is an empirical number assigned to water bodies greater in dimensions than the U.S. Weather Bureau Class A evaporation pans (Linsley and others, 1958, p. 108). No adjustment in these estimates is made for dissolved-solids concentration of the solutions.

Additional evaporation at the Class-I site could reduce the water content of the sludge by about 3 acre-ft/yr ($4 \times 10^{-3}$ $hm^3$/yr) assuming the sludge is discharged to an area measuring 0.5 acre (0.2 ha). The 3 acre-ft/yr ($4 \times 10^{-3}$ $hm^3$/yr) estimate may be high because infiltration at the unlined Class-I site will occur simultaneously with evaporation and the quantity of waste water available for evaporation will be less than 5 acre-ft/yr ($6 \times 10^{-3}$ $hm^3$/yr). Probably 2 to 3 acre-ft/yr (2.5 to $4 \times 10^{-3}$ $hm^3$/yr), or less than one-half the original volume of wastes discharged to the evaporation ponds at the treatment facility, will be available for infiltration.

The quantity of the waste water that would reach the water table is difficult to estimate because it is subject to losses by hydration of the clay, soil evaporation, and transpiration by vegetation, providing the plants were not killed by the toxicity of the effluent. Should the volume of waste water be sufficient to overcome these losses, the specific retention of the sediments in the unsaturated zone must be satisfied before any water is added to the zone of saturation. Inasmuch as the average depth to the water table in the basin is 100 ft (31 m), it might require several years before any effect on the present (1974) ground-water flow system in the basin is noticed.

When hydraulic continuity between the point of surface discharge and the water table is established, the gradients, the velocity, and the quantity of underflow discharged from the basin would increase. To estimate the change in discharge that would result from an increase in recharge, it was first necessary to calculate present (1974) ground-water discharge from the basin. Assuming most of the ground-water flow occurs in the Tropico Group, the present (1974) discharge from the basin as ground-water underflow can be calculated from the equation:

$$Q = KIA \tag{2}$$

where $A$ = cross sectional area of discharging aquifer.

Using $K = 3 \times 10^{-4}$ ft/d ($1 \times 10^{-4}$ m/d), $I$ = 5 ft/mi (0.95 m/km), and $A = 1.6 \times 10^5$ ft$^2$ [$1.5 \times 10^4$ m$^2$; assuming a saturated thickness of 40 ft (12 m) and a width of 4,000 ft (1,220 m)], the discharge ($Q$) is calculated to be $3.8 \times 10^{-4}$ acre-ft/yr ($4.7 \times 10^{-7}$ hm$^3$/yr).

This very low calculated discharge reflects a very low average annual rainfall on the basin of 4 in/yr (100 mm/yr), and losses to evaporation (116.56 in/yr or 3 m/yr) and transpiration that are very high, possibly 30 times the annual rainfall; thus, the volume of water recharged annually to ground-water storage under natural conditions is very small.

The increase in underflow resulting from an increase in recharge is the sum of the present (1974) underflow and the estimated volume of waste water to be discharged at the Class-I site. This sum is equal to about 3 acre-ft/yr ($4 \times 10^{-3}$ hm$^3$/yr). An increase in underflow from $3.8 \times 10^{-4}$ acre-ft/yr ($4.7 \times 10^{-7}$ hm$^3$/yr) to 3 acre-ft/yr ($4 \times 10^{-3}$ hm$^3$/yr) represents a very large and significant change. Equation 2 indicates the hydraulic gradient ($I$), the velocity ($V$), and the saturated thickness of the aquifer ($A$) will change proportionally. A large increase in the saturated thickness of the aquifer ($A$) in the vicinity of secs. 20 and 21, T. 9 N., R. 6 W., could result in an undesirable surface-water flow.

The very low hydraulic-conductivity values (table 2) also suggest there may exist some difficulties in percolating 3 acre-ft/yr ($4 \times 10^{-3}$ hm$^3$/yr). In other words, the volume of wastes may exceed the percolation rate, resulting in a possible saturation of the ground surface outside the boundaries of a potential site. An increase in the dimensions of the waste-discharge site would tend to alleviate this problem by distributing the volume of wastes over a larger area which, in turn, reduces the volume that will have to percolate at a point. Increasing the dimensions of the site would also increase the area of waste-water exposure and thereby the volume of water lost to evaporation. Inasmuch as the rate of evaporation is very high in the study area, many of the problems associated with the percolation of the waste water and the subsequent changes in ground-water movement could be minimized by evaporating the wastes to complete dryness.

## Chemical Quality of Ground Water

Ground-water samples were obtained either by airlifting or by bailing at each test hole. Bailing techniques were used when submergence of the air line or yield to the test hole was inadequate to produce a constant discharge. Although the test holes were gravel packed and surged to induce sufficient yields for sampling, the maximum discharge from any of the test holes pumped by airlift was estimated to be 1 gal/min (0.06 l/s). These low yields made it very difficult to remove water that was introduced during drilling. Water used for test drilling was obtained from the water-supply system at the rocket test center (EAFB-1 and -3, table 3) and was of better quality than the ground water in the study area. The influence of the drilling water on the chemical quality of the ground water in the study area is illustrated by comparing the analyses of water from test holes 9N/6W-17E1, 17P1, and 18Q1 with EAFB-1 and -3 (table 3). Drilling water was also used in the completion of test holes 9N/6W-20E1 and 20E2, but these test holes were pumped for about 12 hours, thereby removing all apparent effects on water quality by the drilling water. No water was used in drilling test holes 9N/6W-19A1 and 9N/7W-12R1, in well 9N/7W-10J1, or in the mine shaft in sec. 20, T. 9 N., R. 6 W.

Ground water in the study area may be generally classified as a sodium chloride type. Although sodium was the dominant cation (+), the milliequivalent anion (-) concentrations indicate a variable dominance by chloride, bicarbonate, and sulfate. The occurrence and high concentrations of these ions and others listed in table 3 probably reflect the presence of volcanic and sedimentary rocks potentially high in soluble minerals combined with a very small quantity of ground-water flow through the system since its time of deposition.

To evaluate the usability of ground water in the Haystack Butte area, results of chemical analyses (table 3) of ground water were compared with generally accepted standards of water quality (table 4). The suitability of water for industrial, domestic, and irrigation use depends to a large extent on the types and concentration of ions and compounds in solution. All widely recognized standards specify that water used for drinking should be clear, colorless, odorless, pleasant to taste, and free from toxic compounds and pathogenic organisms. Widely used criteria in the United States for determining suitability of water for drinking are from the U.S. Public Health Service (1962). Because no limits of acceptability have been established by the U.S. Public Health Service for many of the chemical constitutents often found in water, standards established by the World Health Organization, European (1961) and the World Health Organization, International (1963) are also used here to evaluate the general potability of the ground water in the study area and are summarized in table 4 for comparison (American Water Works Association, 1971).

TABLE 3.--*Chemical*

[Constituents in milligrams per litre; specific

| Sampling point | Date | Depth (feet) | Silica ($SiO_2$) | Total iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9N/6W-17E1 | 1-22-74 | 149 | 34 | 0.83 | 24 | 7.3 | 230 | 2.8 | 300 | 0 |
| 9N/6W-17P1 | 1-22-74 | 120 | 33 | .07 | 25 | 9.3 | 240 | 3.4 | 350 | 0 |
| 9N/6W-18Q1 | 1-22-74 | 218 | 36 | .05 | 23 | 8.1 | 230 | 2.6 | 300 | 0 |
| 9N/6W-19A1 | 1-22-74 | 114 | 20 | .09 | 10 | 82 | 5,700 | 11 | 1,160 | 15 |
| 9N/6W-20E1 | 1-22-74 | 186 | 22 | .06 | 130 | 48 | 830 | 16 | 230 | 0 |
| 9N/6W-20E2 | 1-22-74 | 133 | 6.9 | .03 | 220 | 78 | 2,000 | 17 | 40 | 0 |
| 9N/6W-20M1 (Mine shaft) | 1-21-74 | 130 | 10 | .39 | 24 | 64 | 850 | 17 | 1,330 | 200 |
| 9N/7W-10J1 | 1-21-74 | 254 | 24 | .35 | 100 | 11 | 580 | 9.8 | 1,660 | 0 |
| 9N/7W-12R1 | 1-22-74 | 149 | 30 | .18 | 94 | 27 | 1,100 | 15 | 440 | 0 |
| EAFB-1 | 2-07-72 | -- | 38 | .01 | 26 | 9.7 | 230 | 2.3 | 310 | 0 |
| EAFB-3 | 2-07-72 | -- | 37 | 1.50 | 33 | 12 | 240 | 2.5 | 300 | 0 |

*analyses*

conductance in micromhos at 25°C; and pH]

| Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate + Nitrite as N ($NO_2 + NO_3$) | Dissolved solids | Hardness as $CaCO_3$ | Sodium adsorption ratio (SAR) | Specific conductance | pH | Carbon dioxide ($CO_2$) | Arsenic (As) | Boron (B) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 160 | 130 | 2.0 | 1.7 | 729 | 250 | 11 | 1,200 | 7.9 | 6.1 | 0.053 | 0.97 |
| 160 | 130 | 1.9 | 1.8 | 776 | 290 | 10 | 1,260 | 7.9 | 7.1 | .071 | .98 |
| 160 | 130 | 2.0 | 2.4 | 742 | 250 | 11 | 1,190 | 8.0 | 4.8 | .039 | .94 |
| 5,100 | 5,000 | .5 | .05 | 16,900 | 980 | 130 | 22,900 | 8.4 | 7.6 | .008 | 6.70 |
| 620 | 1,100 | .9 | 1.1 | 2,920 | 190 | 16 | 4,640 | 7.9 | 4.7 | .068 | 1.60 |
| 1,300 | 2,700 | .3 | .84 | 6,520 | 33 | 30 | 10,400 | 8.2 | .4 | .004 | 2.10 |
| 100 | 510 | 1.2 | .07 | 2,480 | 1,400 | 21 | 3,810 | 8.8 | 4.4 | .011 | 2.50 |
| 8.7 | 160 | .2 | .14 | 1,550 | 1,400 | 15 | 2,700 | 7.4 | 106 | .003 | 1.30 |
| 1,100 | 880 | 1.4 | .23 | 3,400 | 360 | 26 | 5,500 | 7.6 | 17 | .047 | 3.60 |
| 160 | 130 | 2.3 | 2.9 | 696 | 260 | 9.8 | 1,260 | 7.6 | 13 | -- | -- |
| 190 | 160 | 1.3 | 2.7 | 784 | 250 | 9.1 | 1,400 | 7.6 | 12 | -- | -- |

TABLE 4.--*Drinking*

[Modified from American Water Works Association

| Chemical constituents | U.S. Public Health Service 1962 | |
|---|---|---|
| | Recommended limit[1] | Tolerance limit[1] |
| Alkyl benzene sulfonate (ABS) | 0.5 | -- |
| Ammonia | -- | -- |
| Arsenic (As) | .01 | 0.05 |
| Barium (Ba) | -- | 1.0 |
| Boron (B)[2] | 1.0 | -- |
| Cadmium (Cd) | -- | .01 |
| Calcium (Ca) | -- | -- |
| Carbon chloroform extract (CCE) | .2 | -- |
| Carbon dioxide, free ($CO_2$) | -- | -- |
| Chloride (Cl) | 250 | -- |
| Chromium, hexavalent ($Cr^{+6}$) | -- | .05 |
| Copper (Cu) | 1.0 | -- |
| Cyanide (CN) | .01 | .2 |
| Dissolved solids (DS) | 500 | -- |
| Fluoride (F) | [5,6].8-1.7 | [5]1.4-2.4 |
| Hardness (as $CaCO_3$) | -- | -- |
| Hydrogen ion concentration (pH) | -- | -- |
| Iron (Fe) | .3 | -- |
| Lead (Pb) | -- | .05 |
| Magnesium (Mg) | -- | -- |
| Magnesium + sodium sulfate | -- | -- |
| Manganese (Mn) | .05 | -- |
| Nitrogen (N), Nitrite + Nitrate[2] | 10.0 | -- |
| Oxygen, dissolved ($O_2$) | -- | -- |
| Phenolic compounds (as phenol) | .001 | -- |
| Selenium (Se) | -- | .01 |
| Silver (Ag) | -- | .05 |
| Sulfate ($SO_4$) | 250 | -- |
| Zinc (Zn) | 5 | -- |

[1]Recommended limit:

USPHS--concentrations which should not be exceeded where more suitable water supplies are available.

WHO, European--concentrations above which may give rise to aesthetic and other troublesome problems.

WHO, International--concentrations which are generally satisfactory to the consumer.

Acceptable limit:

WHO, International--concentrations above which the potability of the water would be "markedly" impaired.

Tolerance limit:

USPHS--concentrations above which shall constitute grounds for rejection of the supply.

WHO, European--concentrations above which are likely to give rise to actual danger to health.

WHO, International--concentrations above which may give rise to actual danger to health.

*water standards*

(1971, p. 20-32); constituents in milligrams per litre]

| World Health Organization European, 1961 | | World Health Organization International, 1963 | | |
| --- | --- | --- | --- | --- |
| Recommended limit[1] | Tolerance limit[1] | Recommended limit[1] | Acceptable limit[1] | Tolerance limit[1] |
| -- | -- | 0.5 | 1.0 | -- |
| 0.5 | -- | -- | -- | -- |
| -- | 0.2 | -- | -- | 0.05 |
| -- | -- | -- | -- | 1.0 |
| -- | -- | -- | -- | -- |
| -- | .05 | -- | -- | .01 |
| -- | -- | 75 | 200 | -- |
| -- | -- | .2 | [3].5 | -- |
| 0 | -- | -- | -- | -- |
| 350 | -- | 200 | 600 | -- |
| -- | .05 | -- | -- | .05 |
| [4]3.0 | -- | 1.0 | 1.5 | -- |
| -- | .01 | -- | -- | .2 |
| -- | -- | -- | -- | -- |
| 1.5 | -- | -- | 1.0-1.5 | -- |
| [7]100-500 | -- | -- | -- | -- |
| -- | -- | [7]7.0-8.5 | [7]6.5-9.2 | -- |
| .1 | [8].3 | .3 | 1.0 | -- |
| .1 | [9].3 | -- | -- | .05 |
| [10]125 | -- | 50 | 150 | -- |
| -- | -- | 500 | 1,000 | -- |
| .1 | -- | .1 | .5 | -- |
| -- | -- | -- | -- | -- |
| [11]5 | -- | -- | -- | -- |
| .001 | -- | .001 | .002 | -- |
| -- | .05 | -- | -- | .01 |
| -- | -- | -- | -- | -- |
| 250 | -- | 200 | 400 | -- |
| 5 | -- | 5 | 15 | -- |

[2]From Public Health Service Pub. 1880, 1969.

[3]Concentrations in excess of 0.2 mg/l indicate need for additional analyses to determine the causative agent.

[4]Recommended limit is 0.05 mg/l for water entering the distribution system; 3.0 after 16-hour contact with new pipes.

[5]Dependent on annual average maximum daily air temperature over not less than a 5-year period.

[6]Where fluoridation is practiced, minimum recommended limits are also specified.

[7]Range, minimum to maximum limits.

[8]In larger installations where removal of iron is economic, water entering the distribution system should not contain more than 0.1 mg/l.

[9]Upper limit should be 0.1 mg/l; 0.3 permitted after 16-hour contact with lead pipes.

[10]Not more than 30 mg/l if the sulfate content equals or exceeds 250 mg/l.

[11]Minimum concentration.

A comparison of the chemical analyses listed in table 3 (excluding EAFB-1, 3) with drinking-water criteria indicates that concentrations of iron, calcium, sulfate, chloride, fluoride, boron, dissolved solids, arsenic, and free carbon dioxide exceeded either recommended, acceptable, or tolerance limits (table 4). According to the U.S. Public Health Service (American Water Works Association, 1971, p. 47), a concentration of chemical constituents in water which exceeds either recommended or acceptable limits does not necessarily constitute a non-potable source; however, to exceed tolerance limits does constitute grounds for rejection of the water supply in that it may be dangerous to health. The concentration of arsenic in ground water sampled from test holes 9N/6W-17E1, 17P1, and 20E1 was 0.053, 0.071, and 0.068 mg/l (milligrams per litre). The tolerance limit for arsenic is 0.05 mg/l. The concentration of iron in ground water sampled from test hole 9N/6W-17E1 and the concentration of fluoride in test holes 9N/6W-17E1, 17P1, 18Q1, and 9N/7W-12R1 were also equal to or in excess of the tolerance limits for drinking water.

A comparison of the concentrations of chemical constituents listed in table 3 with water-quality requirements for industrial use (American Water Works Association, 1971, p. 47) indicates that ground water in the Haystack Butte area is also generally unacceptable for industry. Although the recommended limit for a particular constituent varies with the type of industry, the minimum concentration of dissolved solids in the ground water sampled (except samples from wells 9N/6W-17E1, 17P1, and 18Q1 which were affected by drill water) exceeded all maximum recommended limits. The limits ranged from 100 to 1,500 mg/l. Chloride and sulfate concentrations were also, for the most part, above respective maximum recommended limits of 30 to 250 mg/l and 60 to 250 mg/l.

According to the California Water Resources Control Board (1963, p. 109), water used for irrigation may be classified according to the concentration of particular dissolved chemical constituents. A class-3 water is defined as injurious to unsatisfactory and generally unsuitable for most types of plants. A water containing concentrations of dissolved constituents in excess of the following limits may be classified as class-3 water: specific conductance, 3,000 micromhos; dissolved solids, 2,100 mg/l; chloride, 350 mg/l; sulfate, 1,000 mg/l; and depending on the sensitivity of the plant type, maximum allowable boron concentrations range from 1.25 to 3.75 mg/l. Chemical analyses of ground water in the Haystack Butte area (table 3) indicate that the water is of class-3 type.

## WASTES DISCHARGED TO ABANDONED MINE SHAFTS

According to U.S. Air Force personnel (oral commun., 1973) two mine shafts in sec. 22, T. 10 N., R. 7 W. (fig. 2), were intermittently used for the disposal of wastes from 1960 to 1965. The wastes apparently consisted of toxic and non-toxic liquids and sludges, contaminated soils and metals, and rubbish consisting of chairs, tables, and miscellaneous trash. No records were kept of the exact nature and volume of the wastes, depth of the shafts, or if either shaft contained ground water. In 1964-65, both mine shafts were filled with rock material from the spoil heap. Both shafts were originally dug along mineralized quartz veins in fractured quartz monzonite.

To appraise the potential effects of these wastes on the ground-water quality and any subsequent hazard to public health, extensive hard-rock drilling, chemical analyses, and hydrologic testing of the fractured or unfractured crystalline rock would be required. The location and detection of contaminated or degraded ground water migrating through fractured crystalline bedrock is both an expensive and often nonproductive effort, especially when it must be assumed that (1) the wastes discharged to the shafts were liquid or susceptible to solution if the shafts were partly filled by ground water, (2) the wastes were potentially hazardous to the ground water, and (3) the quartz monzonite is sufficiently fractured to permit percolation of the wastes. Therefore, to determine the effects of the discharge of an unknown quantity of wastes of unknown quality into two mine shafts of unknown depth which are in bedrock would have exceeded the time and money allotted for this study. Consequently, efforts were oriented to a more complete appraisal of the area to be considered for discharge of future Class-I wastes.

## SUMMARY AND CONCLUSIONS

This study evaluates hydrologic parameters that need to be considered in evaluating the feasibility of discharging Class-I wastes in the basin. If a disposal site is selected, locating it above the 2,800-ft (853-m) altitude would avoid possible inundation by flooding, possibly within the areas shown in figure 4. Covering the wastes would minimize wind transport of gases and contaminated soils. The covering of the wastes would be most effective at a time when the liquid content of the sludge had been significantly reduced by evaporation. Protecting native vegetation from dying would allow transpiration from the soils and the unsaturated zones to continue.

Waste water percolating beneath the disposal site would eventually reach the water table. Ground-water movement in the Haystack Butte area is influenced largely by the distribution of the unweathered quartz monzonite bedrock, with most of the flow occurring in an overlying section of volcanic and sedimentary rocks. The direction of ground-water flow is to the southeast at an estimated velocity of $2.8 \times 10^{-7}$ ft/d ($8.5 \times 10^{-8}$ m/d). The quantity of underflow from the basin is approximately $3.8 \times 10^{-4}$ acre-ft/yr ($4.7 \times 10^{-7}$ $hm^3$/yr). Ground-water underflow leaving the Haystack Butte basin becomes part of the regional ground-water system which moves to the Harper Lake playa area. Harper Lake playa is a regional ground-water discharge area. The quality of ground water in the basin is generally unsuitable for domestic, industrial, and irrigation purposes.

Monitoring the effects of the waste discharge could be accomplished by frequently sampling ground water from test holes drilled for this study and other wells near the site. Provided the wastes are not totally dewatered by evaporation, a complete review of the changing hydrologic conditions which would result from an increase in the volume of annual recharge to ground water could be made soon after the discharge of Class-I wastes was begun. This review would verify the hydrologic system as described in this report. Complete evaporation of the wastes could be considered.

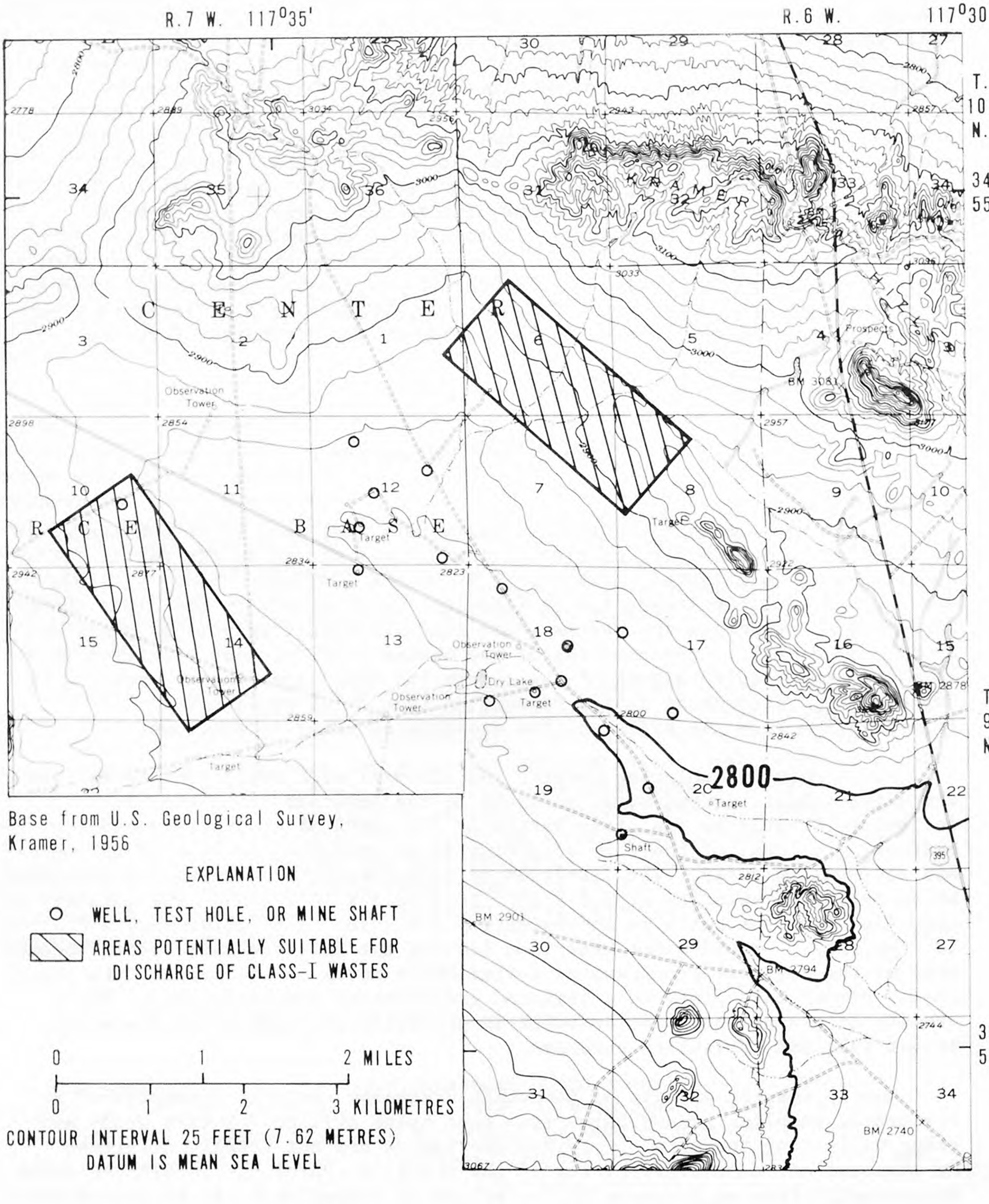



FIGURE 4.--Areas potentially suitable for Class-I waste discharge.

Although usable ground water does not exist in the area investigated, the ground water affected by the discharge of Class-I wastes could at some future time affect potentially usable ground water outside the study area.

The hydraulic-conductivity data used to estimate the ground-water velocity and underflow in this report were from laboratory analyses of drill-core sections from the unsaturated zone from one test hole (9N/6W-19A1). The determination of this important parameter at a single test-hole site by either laboratory or field measurement is probably inadequate when an area is or may be used for disposal of potentially toxic wastes. Therefore, prior to the discharge of Class-I wastes in the basin, a more detailed field determination of areal and vertical variations in hydraulic conductivity of both the Tertiary and pre-Tertiary rocks is needed.

## REFERENCES CITED

American Water Works Association, 1971, Water quality and treatment [3rd ed.]: McGraw-Hill Book Co., 654 p.

Burnett, J. L., and Taylor, G. C., 1973, Potential disposal sites for class-I wastes in southern California: California Div. Mines and Geology Spec. Pub. 44, 12 p.

California Water Resources Control Board, 1963, Water quality criteria, edited by J. E. McKee and W. W. Wolf [2d ed.]: Pub. 3-A, 548 p., [repr. 1971].

_____1972, Waste discharge requirements for waste disposal to land: Disposal site design and operation information: 61 p.

Dibblee, T. W., Jr., 1960, Geology of the Rogers Lake and Kramer quadrangles, California: U.S. Geol. Survey Bull. 1089-B, p. 73-139 [1961].

Gary, Margaret, McAfee, Robert, Jr., and Wolf, C. L., eds., 1972, Glossary of geology: American Geological Inst., Washington, D. C., 805 p.

Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. H., 1958, Hydrology for engineers: McGraw-Hill Book Co., 340 p.

Moyle, W. R., Jr., 1974, Geohydrologic map of southern California: U.S. Geol. Survey, Water-Resources Inv. 48-73, 1 sheet.

National Weather Service, 1936-72, Climatological data.

_____1972, Precipitation-frequency maps for California.

U.S. Public Health Service, 1962, Drinking water standards, 1962: Pub. 956, 61 p.

## APPENDIX: LOGS OF TEST HOLES

| | Thickness (feet) | Depth (feet) |
|---|---|---|

9N/6W-17E1. Drilled by U.S. Geological Survey. Altitude 2,823.73 feet; hole diameter 6 inches; 2-inch polyvinyl chloride casing; perforations 144-149.5 feet; date finished December 1973; water level 112.75 feet below lsd (land-surface datum) (2-25-74).

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, local playa | 3 | 3 |
| Chert, cream to brown | 7 | 10 |
| Sand, medium to fine, with some silt | 27 | 37 |
| Shale, light-gray to light-brown, clay and silt (clay shale, Tertiary) | 42 | 79 |
| Sand, grayish-brown, with silt, some clay; moderately difficult to drill | 29 | 108 |
| Volcanic rocks, weathered, light-gray to brown, some violet; many clay, silt, and sand-size grains; difficult to drill (andesite to basalt?) | 31 | 139 |
| Quartz monzonite, weathered, light grayish-brown, with sand, silt, and much clay-size grains; biotite and muscovite | 11 | 150 |

9N/6W-17P1. Drilled by U.S. Geological Survey. Altitude 2,813.79 feet; hole diameter 4 inches; 2-inch polyvinyl chloride casing; perforated interval 118.5-120.5 feet; date finished December 1973; water level 105.85 feet below lsd (2-25-74).

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown; also some soil | 11 | 11 |
| Sand, light gray-brown, with silt | 17 | 28 |
| Sand, very coarse, with some red clay (weathered volcanic rock or Tertiary section?) | 12 | 40 |
| Clay, brown, with fine sand, some silt; some evidence of oxidation | 8 | 48 |
| Sand, light-gray to light-brown with abundant silt- and clay-size particles (Tertiary shales and sandstones?); moderately difficult to drill | 27 | 75 |
| Quartz monzonite, weathered, light-gray to reddish-gray clay, with quartz grains and lot of biotite; oxidation evident; moderately difficult to drill | 25 | 100 |
| Quartz monzonite, unweathered, gray, with weathered material (clay) in fractures (1-foot core) | 21 | 121 |

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| 9N/6W-18D1. Drilled by U.S. Geological Survey. Altitude 2,818.08 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 43.5-45.5 feet; date finished September 1973; no water. | | |
| Sand, windblown | 3 | 3 |
| Clay, playa, brown, with silt and fine sand | 2 | 5 |
| Gravel, medium | 1 | 6 |
| Clay, brown, with silt and fine sand, very difficult to auger | 3 | 9 |
| Sand, fine, with silt and clay, moderately difficult to auger | 5 | 14 |
| Volcanic rock, weathered, reddish-brown, with silt, sand, and gravel; becomes very difficult to auger with depth | 33 | 47 |
| 9N/6W-18K1. Drilled by U.S. Geological Survey. Altitude 2,804.00 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 44-46 feet; date finished September 1973; no water. | | |
| Clay, playa | 7 | 7 |
| Sand, brown, with silt and clay | 5 | 12 |
| Clay, brown to reddish-brown, with silt and fine sand | 34 | 46 |
| Volcanic rocks, weathered, reddish-brown to black (basalt?), with fine sand and silt, some clay; very difficult to auger | 1 | 47 |
| 9N/6W-18N1. Drilled by U.S. Geological Survey. Altitude 2,818.26 feet; hole diameter 4 inches; 2-inch polyvinyl chloride casing; perforated interval 103-108 feet; date finished December 1973; water level 107.06 feet below lsd (2-25-74). | | |
| Sand, windblown | 4 | 4 |
| Quartz monzonite, weathered, light brownish-gray to light-gray, oxidation, some fine quartz - sand size, much biotite, moderately difficult to drill | 92 | 96 |
| Quartz monzonite, unweathered, clay in fractures, very difficult to drill | 12 | 108 |

| | Thickness (feet) | Depth (feet) |
|---|---|---|

9N/6W-18P1. Drilled by U.S. Geological Survey. Altitude 2,802.40 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 45-47 feet; date finished September 1973; no water.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 1 | 1 |
| Clay, playa | 4 | 5 |
| Silt, buff, with fine sand | 2 | 7 |
| Quartz monzonite, weathered, light brownish-gray to light-gray, oxidation, some fine quartz - sand size, much biotite, moderately difficult to drill | 40 | 47 |

9N/6W-18Q1. Drilled by U.S. Geological Survey. Altitude 2,801.91 feet; hole diameter 6 inches; 2-inch polyvinyl chloride casing; perforated interval 213-218.5 feet; date finished December 1973; water level 93.01 feet below lsd (2-25-74).

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 8 | 8 |
| Silt, buff, with fine sand and some clay | 37 | 45 |
| Sand, coarse | 19 | 64 |
| Clay, brown; very difficult to drill; some biotite (weathered quartz monzonite?) | 8 | 72 |
| Sand, fine to coarse, with some silt, very difficult to drill | 18 | 90 |
| Clay, light-brown to brownish-gray, with silt and sand (weathered quartz monzonite?); very tight | 35 | 125 |
| Clay, light-brown to brownish-gray, with silt, sand, and biotite (weathered quartz monzonite?), very difficult to drill | 115 | 240 |

9N/6W-19A1. Drilled by U.S. Geological Survey. Altitude 2,793.41 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 112-114 feet; date finished September 1973; water level 84.63 feet below lsd (2-25-74).

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 3 | 3 |
| Sand, brown, medium, with some silt | 9 | 12 |
| Sand, dark-brown, with gravel | 3 | 15 |
| Volcanic rocks, weathered (andesite?), green-gray to reddish, violet-brown; clay with silt; fine to medium sand, difficult to auger and drill | 88 | 103 |
| Volcanic rocks, weathered (olivine basalt), black to violet, reddish, with some clay and sand; very difficult to auger and drill | 9 | 112 |
| Quartz monzonite, unweathered, light-gray; much biotite and muscovite | 4 | 116 |

9N/6W-20E1,2. Drilled by U.S. Geological Survey. Altitude 2,787.05 feet; hole diameter 7.5 inches; 2-inch polyvinyl chloride casing (two casings in same hole); perforated interval: 20E1 180-185.5 feet, 20E2 131-133 feet (cement plug at 133-136 feet); date finished December 1973; water level 80.33 feet below lsd (2-25-74) in well 20E2.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay, local playa | 15 | 15 |
| Clay, light reddish-brown to gray, with sand (volcanic rocks?) | 20 | 35 |
| Quartz monzonite, weathered, light-gray to grayish-brown, clay and quartz (sand) dominate, biotite and muscovite, moderately difficult drilling | 102 | 137 |
| Quartz monzonite, mostly unweathered, fractures appear to be filled by weathered quartz monzonite and clay; very difficult drilling | 49 | 186 |

| | Thickness (feet) | Depth (feet) |
|---|---|---|

9N/7W-12D1. Drilled by U.S. Geological Survey. Altitude 2,841 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 38-40 feet; date finished September 1973; no water.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 11 | 11 |
| Sand, brown, with moderate quantities of silt | 6 | 17 |
| Sand, brownish-gray to very gray, medium to coarse, with some gravel | 3 | 20 |
| Sand, light brownish-gray, with silt and gravel, calcium carbonate cement, very difficult to auger | 20 | 40 |

9N/7W-12F1. Drilled by U.S. Geological Survey. Altitude 2,819.00 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 45-47 feet; date finished September 1973; no water.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 2 | 2 |
| Clay, playa | 12 | 14 |
| Silt, brown with fine sand, some clay | 2 | 16 |
| Sand, brown to light grayish-brown, with silt and clay, moderately difficult to auger | 5 | 21 |
| Clay, gray-brown, with silt and fine to medium sand, cemented, difficult to auger | 26 | 47 |

9N/7W-12H1. Drilled by U.S. Geological Survey. Altitude 2,831.5 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 45-47 feet; date finished September 1973; no water.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 9 | 9 |
| Sand, brown to gray, fine to medium, with silt, very uniform; easy to auger | 27 | 36 |
| Sand, brown, medium to coarse, with silt and small gravel, very uniform; easy to auger | 11 | 47 |

| | Thickness (feet) | Depth (feet) |
|---|---|---|

9N/7W-12L1. Drilled by U.S. Geological Survey. Altitude 2,819.78 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 45-47 feet; date finished September 1973; no water.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 1 | 1 |
| Clay, playa, brown to gray, with silt and fine sand, some small gravel | 12 | 13 |
| Sand, brown, with silt and clay | 5 | 18 |
| Volcanic rocks, weathered, with clay, silt and sand; some small gravel, difficult to auger | 29 | 47 |

9N/7W-12R1. Drilled by U.S. Geological Survey. Altitude 2,817.70 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 145-147 feet; date finished September 1973; water level 101.09 feet below lsd (2-25-74).

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown | 2 | 2 |
| Clay, playa, brown to gray, with fine sand and silt | 16 | 18 |
| Sand, buff, very fine | 1 | 19 |
| Silt, buff, with sand and gravel | 3 | 22 |
| Sand, brown, with silt and gravel | 5 | 27 |
| Volcanic rocks, weathered with clay, silt and fine sand, difficult to auger | 97 | 124 |
| Gravel, small with medium sand | 1 | 125 |
| Volcanic rocks, weathered with clay, silt and fine sand, difficult to auger | 22 | 147 |

9N/7W-13C1. Drilled by U.S. Geological Survey. Altitude 2,826.70 feet; hole diameter 8 inches; 2-inch polyvinyl chloride casing; perforated interval 45-47 feet; date finished September 1973; no water.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, windblown with clay or silt from local playa | 4 | 4 |
| Sand, brown, with much silt; moderately tight; moderately difficult to auger | 11 | 15 |
| Clay, brown to light grayish-brown, with silt and fine sand; some biotite (weathered quartz monzonite?) | 32 | 47 |

U.S. GOVERNMENT PRINTING OFFICE: 1975-0-689-909/62